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TO

NAVAL CONSTRUCTOR

Albert Madamet

OF THE FRENCH NAVY,

FORMERLY DIRECTOR OF THE NATIONAL SCHOOL OF NAVAL ARCHITECTURE AND MARINE ENGINEERING, PARIS, FRANCE,

THIS LITTLE BOOK IS DEDICATED BY THE AUTHOR, ONE OF HIS FORMER PUPILS, AS A SLIGHT TOKEN OF APPRECIATION OF THE UNIFORM KINDNESS AND CONSIDERATION SHOWN BY HIM TO THE AMERICAN NAVAL OFFICERS WHO HAVE HAD THE PRIVILEGE OF LISTENING TO HIS LECTURES.

A FRENCH METHOD FOR CONSTRUCTING SLIDE-VALVE DIAGRAMS.

THIS simple and rational method is used for constructing the valve-diagrams of the marine engines in the French Naval Service, and is, without doubt, the only method capable of giving correct results in a simple manner, as it takes into account the angularity of both the connecting-rod and the eccentric-rod.

The method of constructing the curves of piston and valve positions is as follows:

We will consider a vertical inverted engine, stroke 16 inches, throw of eccentric 2 inches. Lay off 16 inches, to any scale, as a diameter (see Fig. 1), and divide the semi-circumference into equal

arcs of 20°, from 0° to 180°, beginning at the bottom. With a radius equal to the length of the connecting-rod between centres, we describe from each position of the crank-pin centre an arc intersecting the vertical continuation of the diameter of the crank-circle. The outside circle is the locus of the positions of the crank-pin centres. We will thus have the line *AB* divided up into irregular intervals, marked 0°, 20°, 40°, etc. These points represent the true piston-positions corresponding to equal arcs passed over by the crank.

We are now able to plot the *curve of piston-positions, MQN.*

Draw a rectangle (Fig. 1) whose height is equal to *AB*, of any length, and divide it up by ordinates perpendicular to *MN*, equally spaced apart, each space to represent 20°, the same spacing we have employed for the crank-circle. By drawing horizontal lines through the points on the line *AB* we will be able to construct the curve *MQN*, which represents the exact position of the piston corre-

sponding to the crank-angle, as shown on the line MN. Thus, if the crank has passed through an arc of 120° from the lower dead-point, the piston has advanced a distance RS or $\frac{RS}{RT}$ in fractions of the stroke.

An inspection of the figure will show at once that the curve is symmetrical about the axis QV. (Fig. 3 shows the above construction very clearly.)

We have thus constructed the curve of piston-positions for a vertical engine. The method for a horizontal or inclined engine is precisely the same, unless the engine is back-acting or is a beam engine. In the case of a beam-engine or a back-acting engine, the movement must be laid down to scale, and the ordinates obtained as before.

The curve of valve-positions may be plotted in precisely the same way as shown for the curve of piston-positions. In this case we consider the throw of the eccentric as the length of the crank-arm, and the length between centres of the

eccentric-rod as the length of the connecting-rod. We have constructed this curve in Fig. 1. ax represents the throw of the eccentric to any scale, ab the length of the connecting-rod (equivalent to the eccentric-rod) to the same scale as ax; $CD = ef$ represents the stroke of the valve to the same scale that ax equals throw of the eccentric. The construction of the curve of valve-positions WXY can be readily understood from Figs. 1 and 3.

In the case where there are two eccentrics, a link, and a suspension-rod, the ordinates of the curve WXY should be plotted from a carefully constructed diagram, or from a model. That is, the actual position of the valve should be obtained for every ten or twenty degrees of rotation of the crank or shaft, and the curve plotted from these measurements. In the case of an engine already completed, these data may be determined directly from the engine itself by means of battens.

We have now described the construction of the two curves.

The construction admits of absolute accuracy if the curves are properly plotted.

The next point to consider will be the relative positions of the two curves.

The angular advance in the case we are considering is 130°, that is, the eccentric is 130° ahead of the crank.

When the valve is in the position D' (see Fig. 1), the piston is at A or the beginning of its up-stroke, or, as shown at M on the curve of piston-positions.

It follows that D' of the curve of valve-positions should be situated on the same ordinate as M. In other words, when the crank is at 0° the piston is at M on the curve MQN (Fig. 1), and the valve is at D', and both should be on the same ordinate; and if we wish to plot the valve-curve on the same diagram as the piston-curve in their proper relative positions, we lay off the angular advance from the middle ordinate to the left, as shown in Fig. 2.

By slipping the valve-curve shown on Fig. 1 to the left until D' is vertically over the ordinate passing through M, we will have the two curves in their proper relative positions, as we see them in Fig. 2.

Having described the construction and the method of putting the curves in their proper relative positions, we are now able to describe the method completely.

The data for the diagram are as follows:

Angular advance of the eccentric..	130°
Width of steam-ports.....	$1''\frac{1}{2}$
Travel of valve, or twice the throw of eccentric.....	$4''$
Upper end:	
Steam-lap.....	$\frac{7}{8}''$
Exhaust-lap.....	$-\frac{1}{2}''$
Lower end:	
Steam-lap.....	$\frac{2\,3}{3\,2}''$
Exhaust-lap.....	$-\frac{3}{16}''$
Length of eccentric rod from centre to centre.....	$33''$
Length of connecting-rod from centre to centre.....	$38''$

By the construction already described we are able to plot the piston-curve $Mb'''uj'N$, and the valve-curve $\phi fg\theta o\phi'''f'$, 130° apart, the valve-curve being 130° in advance of the piston-curve (Fig. 2).

The relative positions of the curves to one another in a vertical direction is of no consequence. We have laid off to the right of Fig. 2 a scale of the stroke of the piston divided into tenths and hundredths of the stroke. Fig. 3 shows the scale of piston-stroke also divided into inches and eighths; also the stroke of the valve into inches and sixteenths.

We will next draw the horizontal line AB, equidistant from the upper and lower horizontal tangents of the curve of valve-positions $\phi g\theta eoqrf'$ (see Fig. 2).

On the left-hand edge of the diagram we will lay off the steam-lap.

The lap on the bottom of the valve we will lay off above AB if positive, and below if negative. The steam-lap being positive in this case and equal to $\frac{3}{32}''$, we lay it off above AB, as shown to the left of the diagram.

We lay off the lap of the top of the valve below AB if positive, and above if negative.

The steam-lap being $\frac{7}{8}''$ on the top of the valve in this case, we lay it off as shown. On both sides we lay off the width of the steam-port $= 1''\frac{1}{2}$.

It seems more rational at first to lay off the top-lap above AB and the bottom lap below AB; this can be done, but we will have to lay off the two curves upside down, which will lead to confusion, so that the method as shown is simpler in the end.

To the right of the diagram we lay off the exhaust-lap of the upper edge above AB if positive, below AB if negative. The exhaust-lap being negative in this case and equal to $-\frac{1}{2}''$, we lay it off below AB, and lay off the width of steam-port as shown.

The exhaust-lap on the bottom of the valve we lay off below AB if positive, and above if negative.

The exhaust-lap on the bottom of the valve being $-\frac{3}{16}''$, in this case we lay it

off above AB as shown, and also lay off the width of steam-port as shown.

On Fig. 8 we see the way of laying off the exhaust-lap when it is positive.

We next draw horizontal lines through w, z, α, and β, and horizontal lines tangent to the valve-curve at g and o.

We are now ready to discuss the diagram.

We will consider the up-stroke of the piston.

The piston is at the bottom of the stroke, crank at 0°, corresponding to the point M of the piston-curve.

The valve-opening at the beginning of the stroke $= \frac{1}{32}'' = \mathrm{w}f$. The lead-angle is $18° 30' = \phi\mathrm{w}$.

The ordinates are measured in inches, the abscissæ in degrees. The ahead motion is from left to right on the diagram, as shown by the arrow.

The valve is moving upward and gradually opens the lower steam-port until it reaches g, when it is wide open: the width of this maximum port-opening is $1''\frac{5}{16}$. The valve then begins its down-

stroke, and gradually closes the lower steam-port until steam is cut off at θ.

We next draw a line through θ perpendicular to AB; it cuts the piston-curve at j and the line MN at i. (AB and MN are parallel.) The distance ij measured on the scale of the stroke to the right of the diagram shows that steam is cut off on the up-stroke at 0.690 of the stroke, or at $16'' \times 0.690 = 11''.09$ from the beginning of the stroke. In terms of the crank-angle this is measured from M to i, which is equal to 118° from the bottom dead-point. We have thus fixed the cut-off on the up-stroke.

We can see that the line $\phi w \theta$ determines the admission and point of cut-off of the steam on the up-stroke of the piston.

Following the valve-curve the next point to consider is K, the piston still being on its up-stroke.

K is the point where the exhaust opens on the lower end of the cylinder, the effect of negative lap on the bottom being clearly shown. We find that the

exhaust opens at K, 0.185 before the end of the up-stroke, or $0.185 \times 16'' = 2''.96$ before the end of the up-stroke, and 47° from the upper dead-point in terms of the crank-angle.

If we wish we can determine the exact position of the valve at any one of these points, K for instance. KK′ being equal to $2''\frac{3}{16}$ shows that the valve is $2''\frac{3}{16}$ from the bottom of its stroke, or $4'' - 2''\frac{3}{16} = 1''\frac{13}{16}$ from the top of its stroke.

The next point is *m*, where the exhaust closes and compression begins on the opposite or upper side of the piston.

The compression in this case begins 26° 30′ before the end of the up-stroke in terms of the crank-angle, and 0.065 of the stroke, or $0.065 \times 16'' = 1''.04$ before the end of the stroke, as shown at *ab*.

The next point to consider is *n*. This is the opening of the steam for the down-stroke or lead, the valve admitting steam above the piston before the end of the up-stroke. The lead-angle in this

case is 15° 30′, the distance $a'b' = 0.020$ of the stroke, or $0.02 \times 16'' = 0''.32$ before the end of the up-stroke.

We will now consider the down-stroke of the piston.

As we have just shown, the steam-lead is 0.020 of the stroke $= 0''.32$, the lead-angle being 15° 30′. The port-opening being $\frac{1}{16}''$ at the beginning of the down-stroke, as shown on *ed.* Maximum opening of steam-port $= 1''\frac{1}{8}$; steam cuts off at p; $i'j' = 0.750$ of the stroke, or $0.750 \times 16'' = 12''$ from the beginning of the down-stroke of the piston, or 115° 30′ from the upper dead-point in terms of the crank-angle.

The exhaust opens on the top 53° before the end of the stroke, and $\pi\rho =$ 0.160 of the stroke, or $0.160 \times 16'' =$ $2''.56$ before the end of the down-stroke.

The compression on bottom or opposite side of piston begins 33° before the end of the down-stroke in terms of the crank-angle and 0.065 of the stroke, or $0.065 \times 16'' = 1''.04$ before the end of the down-stroke, as shown at $a''b''$.

As we stated before, the steam-lead for the up-stroke of the piston is 18° 30′.

$\psi\psi' = 0.02$ of the stroke, or 0″.32 before the end of the down-stroke of the piston.

We have thus considered the movements of the valve and piston for one complete revolution of the crank.

In order to study the effect of a change of lap for either steam or exhaust we have only to draw two horizontal lines, laid off as we have already explained, and we can determine the effect at a glance.

A change of angular advance can be easily studied by tracing the valve-curve on a piece of tracing-paper and moving it over the diagram to the left or right as we wish to increase or decrease the angular advance of the eccentric, taking care, however, to keep the line AB of the diagram coincident with the line AB on the tracing-paper; by doing this we can at once read off the change in port-opening, cut-off, etc.

In case we wish to alter the throw of the eccentric, as in linking up, we must construct a new valve-curve (see Fig. 8).

We are now able to make a complete study of a slide-valve motion for going ahead.

In order to study the diagram for backing, we will assume the angular advance of the backing eccentric to be 130°. The movement in this case is from right to left, and the valve-curve is as shown by the dotted curve $\phi' f' g' \theta' k'' n' o' q' f$. The cut-off, lead, etc., is the same as for going ahead, as a study of the diagram will clearly show.

On Fig. 8 the diagram shows the exhaust-lap to be $+ \frac{1}{16}''$ on top and $+ \frac{1}{8}''$ on the bottom. The valve-curve $g \theta n r$ shows steam admitted at ϕ, cut-off at θ (the piston being on the up-stroke), compression on the opposite or upper side of piston begins at n, and the exhaust opens at K, on the lower side of piston.

On the down-stroke of the piston (steam is admitted bofore the piston reaches the top of its stroke at m) steam

is cut off at p, exhaust closes on the bottom on lower side of the piston at r, where the compression begins. The exhaust opens on the top of piston or to upper end of cylinder at q.

We will next consider the case of a slide-valve admitting steam from the inside edges of the valve commonly known as the D slide.

Fig. 3 shows the valve and piston curves for a cylinder, the valve of which admits steam over the inside edges.

We will consider a vertical inverted engine; stroke of piston 16 inches, travel of valve 4 inches.

The piston is at the bottom of the stroke at M, and we will first consider the up-stroke of the piston. The angular retardation of the eccentric in this case is $90° - 40° = 50°$, as the diagram will clearly show. The valve is beginning to come down, and consequently is admitting steam to the lower steam-port; the steam-lead being equal to $am = 20°$, and the lower port-opening at the beginning of the stroke is $ab = \frac{1}{8}''$. The

lower steam-port is wide open at *c*, a distance equal to $1\frac{9}{32}''$.

The valve then begins to close on the upward stroke, and cuts off at *d*, 60° before the end of the stroke in terms of the crank-angle.

We find by drawing a perpendicular through *d* that it cuts the curve of piston-positions at *p*; $pq = 0.720$ of the stroke, or $0.720 \times 16'' - 11''.52$.

The next point to consider is *r*: this shows that the exhaust has opened to the lower side of the piston, the piston still being on the up-stroke. This exhaust-opening takes place 38° 30′ in terms of the crank-angle before the end of the stroke, and 0.122 of the stroke, or $0.122 \times 16'' = 1''.952$ before the end of the stroke; the exhaust-lap being equal to zero on the bottom of the valve.

Compression begins on the upper or opposite side of the piston at *e*; 28° before the end of the up-stroke of the piston in terms of the crank-angle, and 0.068 of the stroke, or $0.068 \times 16'' = 1''.088$ be-

fore the end of the stroke, as shown at $\alpha\beta$.

Steam is admitted to the upper end of the cylinder, as shown at f, 13° 30′ before the end of the up-stroke of the piston in terms of the crank-angle, and 0.009 of the stroke, or $0.009 \times 16'' = 0''.144$ before the end of the stroke, as shown on perpendicular fy at δ.

The upper steam-port is open a distance $on = \frac{3}{8}''$ at the beginning of the down-stroke of the piston, the valve is wide open for the admission of steam to the upper end of the cylinder at g, the maximum width of opening in this case being equal to $1''\frac{1}{8}$. Steam is cut off at h.

By drawing a perpendicular ts through h we find it intersects the curve of piston-positions at s. $ts = 0.757$ of the down-stroke, or $0.757 \times 16'' = 12''.112$ from the beginning of the down-stroke.

The exhaust opens at i to the upper end of the cylinder 52° before the end of the down-stroke in terms of the crank-angle, and 0.157 of the stroke, or 0.157

$\times 16'' = 2''.512$ before the end of the down-stroke of the piston.

The compression begins at u on the opposite or lower side of the piston 41° before the end of down-stroke in terms of the crank-angle, and 0.100 of the stroke, or $0.100 \times 16'' = 1''.6$ before the end of the down-stroke of the piston.

The steam is admitted again to the lower end of the cylinder before the end of the down-stroke of the piston at m', and the lower steam-port is open a distance $a'\text{K} = \frac{5}{8}''$ at the beginning of the up-stroke of the piston.

We have thus followed a complete cycle of operations of the engine in question.

We will now consider the case of a cut-off valve on top of the main slide-valve.

We will consider the same valve described by Fig. 2, all the conditions being the same.

The cut-off blocks are arranged to admit steam from their outside edges, as

shown by Fig. 5. We have assumed all the conditions of this valve, as it is not the intention of the writer to consider the subject of valve design. The angular advance is assumed to be 180° for the cut-off valve, and the throw of the eccentric is assumed to be four inches (for convenience). It will be readily seen by the following explanation, and also by an inspection of Fig. 8, that a different throw of the cut-off eccentric involves no additional difficulty in understanding or of making use of this method.

In Fig. 4 the full valve-curve and the piston-curve are the same as shown on Fig. 2; the steam-lap being the same in both cases for the main valve.

The valve-curve *ehe'* shown by a broken line, is the cut-off valve-curve with an angular advance of 180°. Its construction is the same as shown on Fig. 1. In this case it is the same as the main valve-curve.

We assume the conditions of Fig. 5. We will consider first the lower steam-port and the up-stroke of the piston.

With a pair of dividers take off the distance $ab = 1''\frac{5}{8}$ from Fig. 5 (the cut-off blocks being in mid-position relative to the top of the main valve).

With this constant distance ab construct the curve $f'b''xt$, which is vertically above the cut-off valve-curve the constant distance $ef' = b''b''' = hh' = te'$. This simple construction is all that is necessary.

It shows:

The cut-off valve cuts off at b'' or 0.483 of the up-stroke of the piston. The cut-off valve opens the lower main valve-port again at x, but the main valve has already closed at θ. The lower steam-port in the main valve remains open from x to b'' again.

We will now consider the upper steam-port. As before, with a pair of dividers we take off the distance cd, Fig. 5, and lay it off below the cut-off valve-curve he'; the vertical distance between these two curves $= cd$ (Fig. 5) $= d^{IV}d''' = e't'$. This will give us the curve $c''z$; and we at once see that the cut-off valve closes

at c'', which corresponds to 0.536 of the down-stroke of the piston. The cut-off valve opens the main valve-port again at z, but the main valve has already closed at p, and the cut-off valve is open until it closes again at c''.

If we wish to study the effect of separating the blocks we will assume the lower block advanced $\frac{5}{32}''$, and the upper one $\frac{1}{4}''$ from the centre-line. This will give us $(1''\frac{5}{8} - \frac{5}{32}'')$ for the constant vertical distance of the curve $a''y$ from the cut-off valve-curve eh; and we will find, as before, cut-off valve cuts off at a'', or 0.415 of the up-stroke, and opens again at y long after the main valve has closed at θ. The consideration of the upper end of the valve is the same; the constant distance to be laid off vertically below the cut-off valve-curve he' equals $(1''\frac{1}{2} - \frac{1}{4}'')$. We readily see that steam is cut off by the cut-off valve at d'', or 0.430 of the down-stroke of the piston. The cut-off valve opens the steam-port on main valve again at w, but the main

valve has already closed the main steam-port to the cylinder.

The curves $a''y$, $b''x$, $d''w$, and $c''z$ are all that is necessary to show the points of cut-off for different distances between the cut-off blocks, and any number of curves may be constructed in the same manner; and *vice versa* a point of cut-off may be determined and a curve passed through it in the same way we have already shown. By completing the curve $b''x$, for example, we readily find the distance between the edges of the cut-off block and the main valve-port, as the distance measured vertically from the main valve-curve $fg\theta n$ will show the distance between edges of cut-off and main valve from $f'f$ to b'', where it becomes zero. This distance is not, strictly speaking, equal to ff'', as the port is only $1''\frac{3}{8}$ wide, so that we see the steam-port in the main valve is wide open for a portion of the stroke until the vertical distance between the curves $f'b''x$ and $fg\theta$ is less than $1''\frac{3}{8}$, when the port on the main valve is gradually closed until

it closes at b''. This should be seen at once without any further explanation.

It is hardly necessary to go over the same explanation for the other end of the valve.

If we continue the curves $c''z$ below the limits of the diagram, we will have the same condition of affairs as above.

The curve $f'b''xt$ has been constructed to show that the cut-off valve only closes the lower main valve-port at b'' when the main steam-port is open to live steam-and only closes the upper main valve-port at c'' when the main steam-port is open to live steam.

The lower main valve-port is open to steam from x to t and from f' to b'', so that it is only closed from b'' to x.

In the same way the upper main valve-port is only closed from c'' to z.

The same explanation applies equally to the curves $a''y$ and d''w, and any other similar curves constructed for the variable distance between the cut-off blocks.

We can thus follow the combined

movements of the main and cut-off valves without confusion and with very little trouble.

The concentric curves $b''x$, $a''y$ may be any distance apart. Let us assume that every turn of the hand-wheel of the cut-off gear will advance the lower block a certain distance and the upper block a certain distance. With these constant distances we can construct any number of concentric curves. By *concentric* in this case is meant that the vertical distance between the curves is a constant quantity.

In the case where steam is admitted by the inside edges of the cut-off blocks the angular advance would be 360° or 0°, and the cut-off valve-curve would be $Mb'''hc'''N$ (Fig. 6).

The distances of the inner edges of the cut-off blocks from the inner edges of the main-valve steam-ports (when the cut-off blocks are in mid-position on the top of the main valve, as shown on Fig. 7) are the constant distances to be used for laying off the curves $f'b''h'xt$

and $zh''c''$ above and below the cut-off valve-curve. The constant distance $b'''b'' = hh' = Nt = Mf'$ is the distance ab, Fig. 7.

The constant distance $hh'' = c'''c''$ is the distance cd, Fig. 7.

We readily see from the diagram (Fig. 6) that the lower port in the main valve is open for the admission of steam to the lower end of the cylinder at x a short time before the main valve opens at ϕ'''. (The main-valve and piston-curves are the same as we have already considered in Figs. 2 and 4.)

We thus see that the cut-off blocks open the port at the lower end of the main valve at x and cut off at b'', or 0.410 of the stroke of the piston; the main valve cutting off at θ later. At the upper end of the main valve steam is admitted at z before the main valve opens at n and cuts off at c'', or 0.480 of the stroke of the piston; the main valve cutting off at p later.

We have thus considered the principal cases that occur in practice, and no

difficulty should be experienced in applying this method to any case where the slide-valve is moved by an eccentric.

We have employed the same valve-curves throughout for convenience, but it will be readily seen that the throw of the valve would make no difference in the construction of the diagram.

Fig. 8 has been constructed to show the appearance of valve-curves of different travel and different angular advance.

The effect of using the link to cut off shorter is clearly shown in this diagram. The shorter the link, the greater the angular advance, and the less the travel of the valve.

All of the effects of shortening the link are shown very clearly. The ordinates of the curves may be obtained from a model or from a diagram of the link-motion.

The writer considers the above method far superior to any existing methods, both in regard to accuracy (as the angularity of the eccentric-rods is taken into account) and clearness. In fact, the

above method seems to be a remarkably clear and rational method for teaching the theory of the slide-valve from the simple locomotive slide to the Meyer cut-off, together with the action of the link, as shown on the diagram of Fig. 8, when used to vary the point of cut-off.

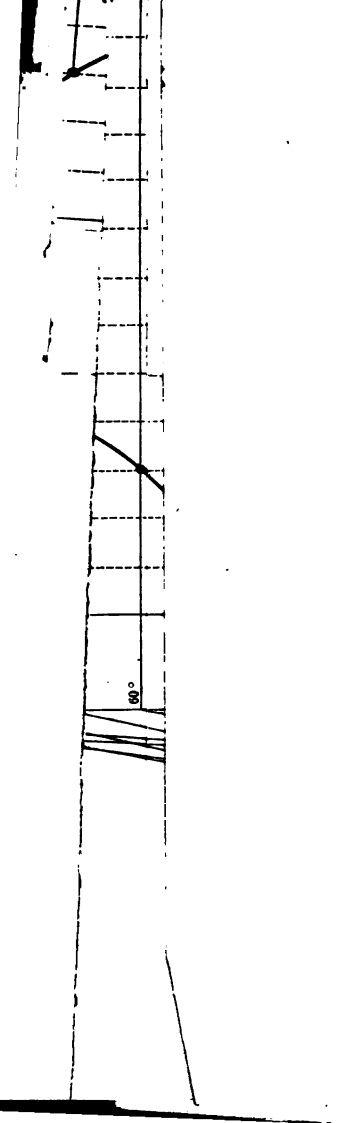
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Fig. 8.

Showing Effect of Cha

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